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Kylee K. Kleppinger
School of Natural Resources
The Ohio State University
Columbus, OH 43210
740-225-9706; E-mail kleppinger.3@osu.edu

THE EFFECTS OF LAND USE CHANGES ON NORTHERN BOBWHITE (*Colinus virginianus)* ABUNDANCE IN SOUTHWEST OHIO

KYLEE K. KLEPPINGER,[a] School of Natural Resources, The Ohio State University, Columbus, OH 43210, USA

Abstract: Although many factors are known to contribute to the population declines of the northern bobwhite (*Colinus virginianus*), in the Midwestern U.S. the greatest threat to northern bobwhite populations is thought to be dramatic changes in land use. Over the past century, the shift away from a diverse landscape characterized by low-impact agriculture to a landscape dominated by hardwood forests, invasive agricultural practices, and increasing development is believed to have drastically reduced habitat suitability for the northern bobwhite. No study thus far had addressed these issues in southwest Ohio. Nine routes (4 low abundance, 5 high abundance) were chosen based on call count data collected from 1984-2003. Routes with an average of 2 or fewer bobwhites detected per year were classified as low abundance, and routes with an average of 5 or more bobwhites detected along them were considered high abundance. After covermapping all 9 of these routes, I digitized existing habitat surrounding call count stops in GIS and outputted the percentages of different habitat types. Call count data collected by the Ohio Division of Wildlife from 2003-2005 was compared with these habitat percentages, t-tests were run on individual habitat variables, and information theoretic methods (AIC) were used to evaluate the fit of 19 constructed logistic regression models, including one

[a] Email: kleppinger.3@osu.edu

null model. Only the model containing developed habitat scored higher than the null model but not high enough to indicate any significant relationship between bobwhite occurrence and the habitat variable. The results indicate that potential bias might exist in the viability of call count routes as a true measure of quail abundance. Bias could also be related to small sample size.

Key Words: Akaike's Information Criterion, *Colinus virginianus*, habitat, land use changes, logistic regression, northern bobwhite, southwest Ohio, whistle count survey

INTRODUCTION

The northern bobwhite (hereafter bobwhite) is an ecologically important bird that has a nearly fifteen thousand year history on the North American continent. According to Rosene (1969), this species of quail derives its common name from its distinctive call. In the spring and summer, the males whistle *bob white* or *bob bob white*, a call by which most people can easily identify this bird. Although common names vary regionally, the use of systematics has allowed taxonomists to accurately classify the bobwhite quail based on its evolutionary origins. The bobwhite is of the order *Galliformes*, which are chicken-like birds that have feet adapted for scratching, and it belongs to the family *Odontophoridae*, which is the family to which all American quails belong. The scientific name (genus and species) of the bobwhite is *Colinus virginianus* (Rosene 1969). The bobwhite is a very distinct species with several closely related subspecies that inhabit other parts of North America (Elliott 1974).

Bobwhites are largely resident birds with poor dispersal abilities. They spend most of their lives on the ground, and the foods they eat reflect this life history. In general, quail feed on a wide variety of seeds and insects. Many times the quail food supplies depend largely on the agricultural practices of the previous summer and fall (Roseberry and Klimstra 1984). The period of greatest food abundance is autumn, and spring is a period of relative food scarcity. In the fall, just following crop harvest, there is an abundant amount of seeds available, and because the weather is still warm, there are also abundant insects that are readily available for bobwhite consumption. During this time of the year, quail tend to favor legume seeds to seeds of other plant families. The main seed crop is not yet produced in spring and the weather is not warm enough for insects. A few plant species set seed in late March and April and often comprise the bulk of the quail's diet during this time. During the summer, bobwhites seem to adjust their diets to include as many insects as needed to meet the high protein requirements of egg laying (Rosene 1969).

Bobwhites depend on various seral stages of early successional plant communities for brood-rearing, nesting, foraging, and roosting (Greenfield 2002). Rosene (1969) also reported that the best managed quail ranges include woody, annual, and perennial herbaceous plants growing in association with one another (Rosene 1969). The overstory of the woodland must be thin enough to allow an understory to grow and create ground cover with the proper density. This type of cover is found in idle fields, open woodlands, crop fields such as corn and soybeans with weedy growth, and certain types of pastures. For protection, small shrubby thickets are needed on every 15 acres in the open woods or on field edges.

Historically, there have been many factors that have contributed to the mortality of bobwhites. One such factor is weather. Bobwhites are particularly susceptible to extreme cold, and freezing conditions are most associated with short-term population declines (Rosene 1969). Hunting is also a source of bobwhite mortality, but it is only one of a number of factors in the rise and fall of quail populations in any given area (Elliott 1974). Predation, however, is the primary source of mortality for bobwhites at all life stages. Estimates of predation rates on quail nests are usually high, and hatching success rates vary from 12 to 50%. Mammals such as striped skunks (*Mephitis mephitis*), opossums (*Didelphis virginiana*), gray foxes (*Urocyon cinereoargenteus*) and raccoons (*Procyon lotor*) are the most important group of nest predators, followed by several species of snakes, and occasionally bobcats (*Lynx rufus*) and armadillos (*Dasypas hovemcintus*) (Rollins and Carroll 2001).

The northern bobwhite is currently declining throughout most of its range. Some people, hunters and anti-hunters included, believe that broad-scale hunting restrictions are needed to save this species from endangerment and possible extinction. Many biologists, however, do not believe that over-harvest is the primary cause of long-term decreases in quail populations (Peterson 2001). Another potential factor contributing to reduced bobwhite numbers may be the affect of agricultural chemicals on the survival of quail chicks. Mortality of quail chicks may be linked directly or indirectly to anticholinterase insecticides (Palmer 1998). The greatest threat to bobwhite populations, though, is thought to be dramatic changes in land use over the last 80 years. Because bobwhites are dependent on early successional woodlands for survival, the shift away from a landscape dominated by diverse, low-impact agriculture in the early twentieth century to landscapes dominated by hardwood forests and intensive pine silviculture in the latter twentieth century has reduced habitat suitability for bobwhites (Rollins and Carroll 2001). As the landscape has changed, it has also become more fragmented. Bobwhites, with their notoriously poor dispersal abilities, have been unable to adapt to this increased fragmentation, and population isolation may also be a factor in decreased bobwhite presence.

Northern bobwhites are an ecologically and economically significant species in Ohio. Ecologically, they are a very sensitive indicator species, especially in agricultural landscapes where they are most affected by fragmentation and intensive agricultural practices. These birds are also ideal game birds and are extremely important to the hunting community. Because the northern bobwhite is recognized as a harvested species, they are also indirectly important to the economy. If bobwhite populations continue to decline, reduced hunter participation could result in significant economic losses (Burger 1999).

The research conducted on northern bobwhites has been extensive. The first research specifically devoted to this species took place in Illinois and was a limited nesting and population study in 1938 (Roseberry and Klimstra 1984). Based on the results of this study, bobwhites were thought to be heading toward extirpation in southern Illinois. The Breeding Bird Survey also indicates that northern bobwhite populations declined -2.8% per year in the southeastern United States during 1966-1999 (Rollins and Carroll 2001). No research thus far, however, has specifically targeted the declining bobwhite populations in southern Ohio.

Throughout the course of this study, my goal was to quantitatively assess and compare land use between quail routes in southwestern Ohio that have stable versus declining populations in an effort to determine which land uses, if any, are better suited for maintaining stable bobwhite populations. Based on previous research, I expected that routes containing a good mixture of grassland (pastures, hayfields, old fields, and warm and cool season grasses) and wooded areas would be positively associated with bobwhite presence, while routes containing large amounts of active cropland (corn, soybeans, wheat, and oats) and developed areas, including residential, commercial, and park areas, will be negatively associated with bobwhite occurrence. Some of these habitat types may singularly affect quail populations, while some may affect them in combination. For example, the presence or absence of developed areas may singularly have an impact on bobwhite populations, while areas that have a combination of forest and grassland may affect bobwhites in concert. As one habitat increases, the other will decrease and vice versa.

METHODS

Habitat Mapping and Classification

To determine which call count routes would be used for this study, whistle count survey data collected by the Ohio Division of Wildlife from 1984 to 2003 was used to determine past and present population levels along several quail routes in southwest Ohio. Low abundance routes were defined as having an average of less than or equal to 2 quail detected on each route in recent years, and high, stable population routes were defined as having an average of greater than or equal to 5 quail detected on each route in recent years. Based on these criteria, 9 routes (four low population and five high population routes) in 7 different counties, including Butler, Clinton, Greene, Miami, Montgomery, Preble, and Warren counties, were chosen for this study (Figure 1). Each of these counties contained 1-4 survey routes depending on existing bobwhite habitat, with the majority of the counties having 4 routes. Each route was distributed across 3 townships and consisted of 12 listening stations no closer than 1 km apart, placed initially near quality bobwhite habitat. The number of bobwhites heard calling at each station, the total calls heard at each station, and the number of bobwhites seen at each station was recorded.

Figure 1. A map of southwest Ohio that includes Butler, Clinton, Greene, Miami, Montgomery, Preble, and Warren counties, the counties in southwest Ohio in which the routes used in this study were located and covermapped in 2004.

The most recently updated aerial photos from 2002 were obtained from the National High Altitude Aerial Photography Program. Maps encompassing the area within 1 kilometer of each quail stop from each of the 9 routes was downloaded and printed. All routes were driven and covermapped during the summer of 2004, and current habitat configurations for each stop were marked on the 2002 maps. The landcover classifications used to identify specific habitat types were the same for all routes and consisted of 14 specific habitat classifications that are based on known bobwhite habitat requirements. After covermapping was completed, the specific habitat classifications were combined into broader categories for data analysis (Table 1).

Figure 2. Specific habitat classifications based on known quail habitat requirements that were used to covermap both high and low abundance routes in southwest Ohio in 2004. The specific habitat classifications were combined into broader categories for data analysis.

Combined Habitat Classifications	Specific Habitat Classification
Total Crop	Active Cropland (corn, soybeans)
	Small Grains (wheat, oats)
Total Herbaceous	Pasture/Hay
	Old Field
	Grass/Forbs - warm season (70% grass)
	Grass/Forbs - cool season (70% grass)
	Wetland
Total Wooded	Open Woodland (crowns not touching)
	Closed Woodland (crowns touching)
Total Fencerow	Herbaceous Fencerow (divide ag fields, 2-3 m wide)
	Shrub/Scrub Fencerow (divide ag fields, 2-3 m wide, single crown width*)
	Mature Tree Fencerow (divide fields ag fields, 2-3 m wide, single crown width*)
Total Developed	Park/Cemetery
	Residential (houses, buildings, yards, businesses, etc.)

* >single crown width should be classified as open or closed woodland

Once covermapped, the aerial photos for each route were imported into Arcview Geographic Information Systems 3.2, and the existing habitat within 1 kilometer of each individual stop was digitized onto the photographs (Figure 2). GIS was then used to output areas and percentages of each of the different habitat types for each stop (stop level data). The percentages of each habitat type from the stop level data were then summed to produce the total percentage of each habitat type per route (route level data).

Figure 3. Land uses digitized in GIS within 1 km of Stop 3 along Miami County-Call Count Route 3 in southwest Ohio. Land uses seen were covermapped in summer, 2004.

Statistical Analyses

Univariate Analysis. -- The call count data for 2003, 2004, and 2005 obtained from the Ohio Division of Wildlife was used to calculate the average number of quail heard per year for each route, and these data were also used to obtain the average number of quail heard per year at each stop. The route level and stop level habitat data outputted from GIS were transformed using arcsin transformation. This transformation conducted on data proportions removed extreme high and low proportions and normalized data. Transformed data was used to run t-tests on the specific habitat types and the combined habitat categories at both the route and stop level. All t-tests were considered significant at $P<0.10$.

Multivariate Analysis.—Each single habitat variable had some influence on the probability of detecting quail at a particular stop, however, no one habitat type likely determines bobwhite habitat quality by itself. Logistic regression was used to understand the influence of every habitat variable in the presence of other variables when the other variables were held at their means. This involved modeling the probability of detecting quail at a stop as a function of one or several variables combined as a set of candidate models. In this study, the dependent variable was the presence or absence of bobwhites at each stop, and the independent variable was one or more of the habitat types. In order to relate specific habitat variables to bobwhite occurrence, I constructed 19 candidate models (single-variable additive models, 2-variable additive models, 3-variable additive models, and 2-variable compensatory models) based on what is known of current habitat configurations and preferred bobwhite habitat.

For single-variable additive models, I hypothesized that wooded, herbaceous, and fencerow habitat would positively affect the probability of bobwhite detection, and crop and developed habitat would have a negative effect. For 2-variable additive models, I predicted that herbaceous+woody habitat, woody+fencerow habitat, and crop+fencerow habitat would positively effect the probability of bobwhite detection, while herbaceous+developed habitat, crop+herbaceous habitat, and crop+woody habitat wood negatively effect bobwhite detection. In terms of 3-variable additive models, I hypothesized that crop+herbaceous+fencerow habitats would positively affect bobwhite presence, while crop+developed+herbaceous habitats would have a negative effect. Four 2-variable interactive models were also developed. This type of model could also be described as a compensatory habitat model. It assesses the probability of detecting quail in an area where one habitat type is increasing and another habitat type is decreasing proportionally. These models included (crop x fencerow) habitat which I predicted would positively effect bobwhite presence, as well as (crop x herbaceous) habitat, (herbaceous x developed) habitat, and (crop x developed) habitat which I hypothesized would all have a negative effect on bobwhite presence.

In addition to these models, a null model and a full model were also constructed. The full model was an additive model containing every possible explanatory variable (crop+herbaceous+woody+fencerow+developed), while the null model was an average of bobwhite abundance only and contained no explanatory habitat variables.

I employed information theoretic methods to direct model selection,. For all 19 models, Akaike's Information Criterion including a correction for small sample size (AICc) was calculated. The fit of the various candidate models were compared using ΔAICc values, the difference between the AICc value of a particular model and the lowest AICc value within the model set. In addition, the AICc weighted (AICcW) values were used to consider the relative weight of evidence that a particular model was the best supported model. Overall, the model with the lowest score was the one that best fit the data.

RESULTS

Univariate Analysis

The means and standard deviations of the raw habitat data outputted from GIS varied widely for both specific habitat categories (Appendix A) and combined habitat classifications (Appendix A). T-tests of transformed data conducted singularly on each combined habitat type at the route level produced no significant differences between habitat present along low routes and habitat present along high routes (Table 2). At the stop level, there were also no significant differences detected between high and low routes (Table 3).

Table 1. Summary of T-test statistics (means, standard deviations, *t* values, and *P* values) for the condensed habitat types at the route level. T-tests were run on the transformed data with significant difference defined as p<0.10 based on habitat areas covermapped in 2004 along high and low call count routes located in southwest Ohio.

	Combined Habitat Types				
Route Level T-test Statistics	T Crop	Herbaceous	Woody	Fencerow	Developed
High mean (sd)	0.81 (0.20)	0.30 (0.05)	0.45 (0.09)	0.02 (0.03)	0.33 (0.10)
Low mean (sd)	0.71 (0.08)	0.28 (0.11)	0.56 0.14)	0.03 (0.03)	0.36 (0.11)
t value	0.96	0.22	-1.38	-0.33	-0.43
P value	0.38	0.84	0.23	0.75	0.68

Table 2. Summary of T-test statistics (means, standard deviations, *t* values, and *P* values) for the condensed habitat types at the stop level. T-tests were run on the transformed data with significant difference defined as p<0.10 based on habitat areas covermapped in 2004 along high and low call count routes located in southwest Ohio.

	Combined Habitat Types				
Stop Level T-Test Statistics	T Crop	Herbaceous	Woody	Fencerow	Developed
High mean(sd)	0.80 (0.32)	0.28 (0.13)	0.43 (0.20)	0.01 (0.03)	0.31 (0.14)
Low mean(sd)	0.74 (0.18)	0.26 (0.17)	0.51 (0.16)	0.01 (0.03)	0.36 (0.15)
t value	0.34	0.58	-1.8	-0.65	-1.15
P value	0.73	0.57	0.12	0.52	0.25

The call count data collected in 2003, 2004, and 2005 showed an overall low average number of bobwhites heard per stop per year along each route. Moreover, the average frequency of occurrence of bobwhites along these routes (the average proportion of stops where bobwhites were heard calling) was also markedly low (Table 4).

Table 3. A call count summary of the number of quail detected per route in 2003, 2004, and 2005 along 9 routes in southwest Ohio. The average number of quail heard per year and the average frequency of occurrence per year were calculated using data provided by the Ohio Division of Wildlife whistle count surveys.

Abundance	Route Name	2003	2004	2005	Average Number of Quail Heard Per Year	Average Frequency of Occurrence Per Year (%)
Low	Greene 2	0	0	0	0.0	0.0
	Greene 3	1	0	0	0.3	2.8
	Miami 3	0	1	0	0.3	2.8
	Montgomery 1	0	0	0	0.0	0.0
High	Butler 4	8	9	0	5.7	19.4
	Clinton 3	8	10	8	8.7	36.1
	Montgomery 2	7	12	6	8.3	30.6
	Preble 2	7	8	4	6.3	25.0
	Warren 2	19	10	12	13.7	44.4

Multivariate Analysis

Of the logistic regression models used, all graphs of the single habitat variables (Figures 4-8) had a similar effect on the probability of detecting quail at a given stop. Only the model assessing developed habitat (Figure 8) differed, indicating that a very low amount of developed habitat at a certain stop was positively associated with quail occurrence. These results coincided with the AICc calculations of the 19 candidate models of which the single-variable additive model containing developed habitat was the lowest scoring (most parsimonious) model and was the only model to score higher than the null model. Even though the developed habitat model had the lowest AICc score, the difference between the developed model score and the null model score was very small (0.665) and not significant enough to indicate any real correlation between habitat and bobwhite occurrence (Table 5). All other candidate models had higher AICc values than the null model, and overall, I found no evidence that habitat coverage had any relationship to the number of bobwhites found at each stop. In the end, the best predictor of detecting bobwhites along these routes was the average number of bobwhites seen along these routes in previous years. The chances of detecting bobwhites did not improve by assessing the existing habitat.

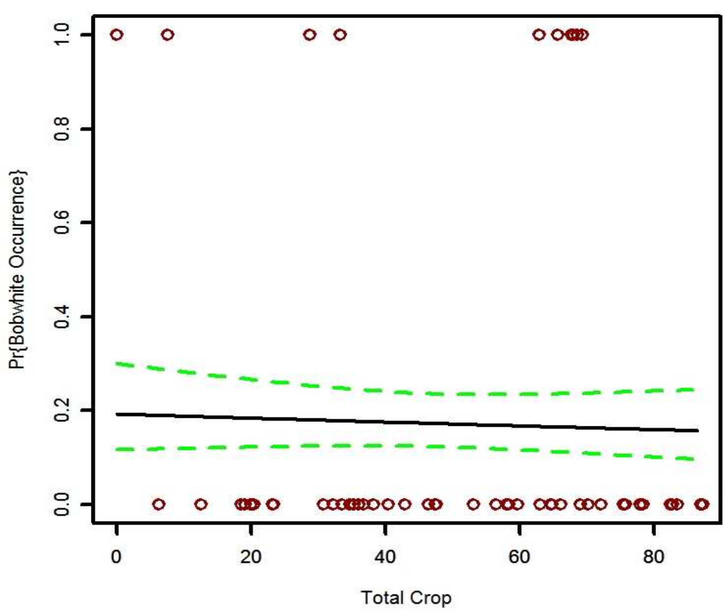

Figure 4. Logistic regression model assessing total crop habitat as a predictor of bobwhite occurrence along high and low routes in southwest Ohio from 2003-2005.

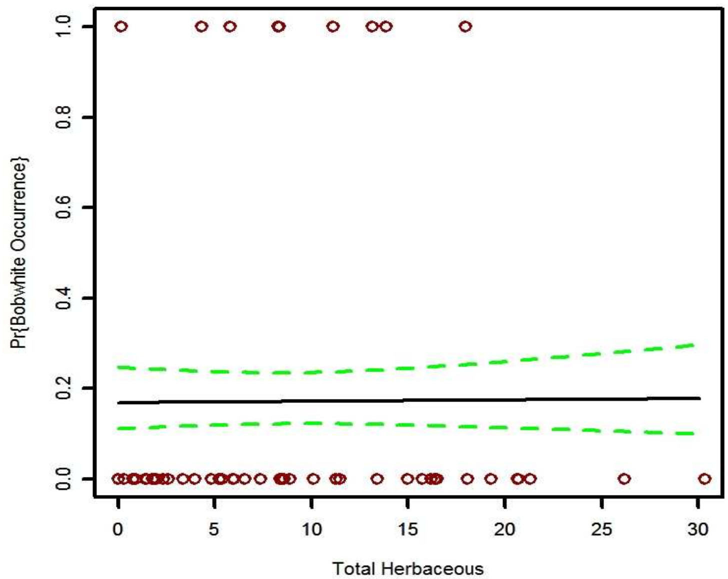

Figure 5. Logistic regression model assessing total herbaceous habitat as a predictor of bobwhite occurrence along high and low routes in southwest Ohio from 2003-2005.

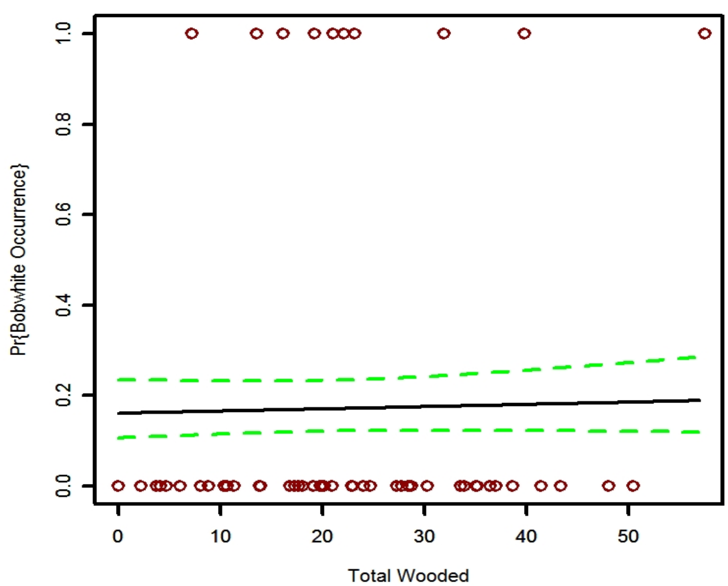

Figure 6. Logistic regression model assessing total wooded habitat as a predictor of bobwhite occurrence along high and low routes in southwest Ohio.

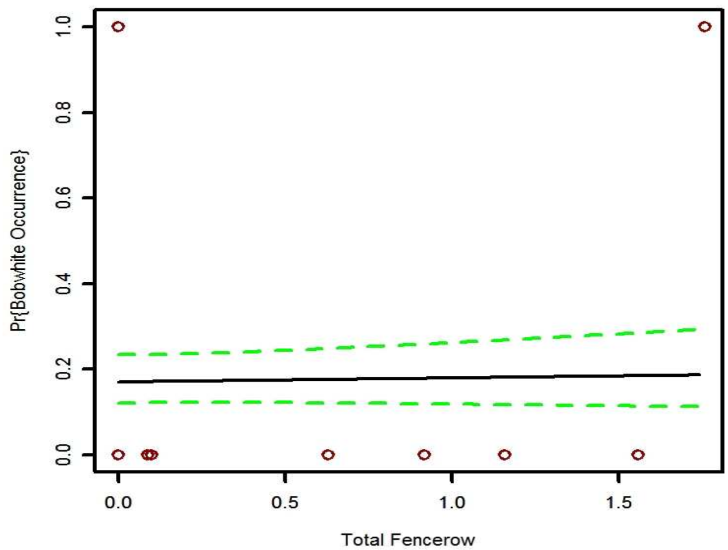

Figure 7. Logistic regression model assessing total fencerow habitat as a predictor of bobwhite occurrence along high and low routes in southwest Ohio from 2003-2005.

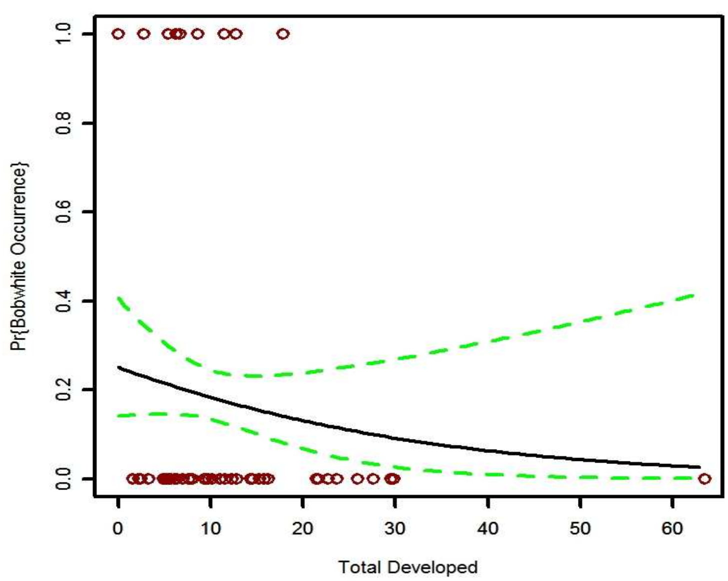

Figure 8. Logistic regression model assessing total developed habitat as a predictor of bobwhite occurrence along high and low routes in southwest Ohio from 2003-2005.

Table 4. A summary of Akaike's Information Criterion (AIC) calculations for the 18 candidate models developed as predictors of bobwhite occurrence along high and low call count routes in southwest Ohio from 2003-2005. "k" is the parameter (model) used, AIC is the uncorrected AIC value, AICc is the AIC value corrected for small sample size, ∆AICc is the difference between a particular AICc value and the lowest (most parsimonious) AICc value, and AICcW is a weighted AICc value that considers the likelihood that a particular model was the best supported model.

	k	AIC	AICc	∆AICc	AICcW
Developed	1	59.929	53.160	0.000	0.226
Null Model [a]	2	53.750	53.825	0.665	0.163
Herbaceous + Developed	3	54.878	55.349	2.188	0.076
Woody	4	55.133	55.364	2.204	0.075
Fencerow	5	55.455	55.686	2.526	0.064
Total Crop	6	55.652	55.883	2.723	0.058
Herbaceous	7	55.750	55.980	2.820	0.055
Total Crop + Developed + Herbaceous	8	55.234	56.034	2.874	0.054
Total Crop x Developed	9	55.416	56.216	3.056	0.049
Herbaceous x Developed	10	55.994	56.794	3.634	0.037
Fencerow + Woody	11	56.738	57.208	4.048	0.030
Total Crop + Woody	12	57.038	57.508	4.348	0.026
Herbaceous + Woody	13	57.120	57.591	4.430	0.025
Total Crop + Fencerow	14	57.257	57.727	4.567	0.023
Total Crop + Herbaceous	15	57.622	58.093	4.933	0.019
Total Crop + Herbaceous + Fencerow	16	59.243	60.043	6.883	0.007
Total Crop x Fencerow	17	59.246	60.046	6.885	0.007
Total Crop x Herbaceous	18	59.506	60.306	7.146	0.006
Full Model[b]	19	65.472	70.472	17.312	3.940E-05

[a] The null model was an average of bobwhite occurrence only and contained no explanatory habitat variables.

[b] The full model contained every possible explanatory habitat variable (crop+herbaceous+woody+fencerow+developed).

DISCUSSION

Based on previous research done and the literature available, it was expected that land uses would differ significantly between high quail routes and low quail routes. This prediction, however, was supported by neither the univariate nor the multivariate data analyses. Although the logistic regression model containing developed habitat scored better than the null model, the ∆AICc value was very small and not significant enough to indicate any real correlation between habitat and bobwhite occurrence. Even though these routes represented a boundary between high and low quail abundance areas in southwest Ohio, there were no significant differences in the habitat present. These results could have occurred for a number of reasons, including bias in call count detection and the selection of the specific habitat types measured.

In this study, much of the potential bias could have come from the call count routes themselves. Because the call counts recorded only came from single males calling, whether or not these routes are actually a good measure of bobwhite abundance is questionable. Bobwhite detectability along these routes is also a point of concern, and detectability in certain habitat types may be difficult. Developed areas, for example, are often characterized by increased noise levels which may hinder an observer's ability to hear bobwhites calling. The low number of routes used in this study could be another source of statistical bias. Small sample size could have been a reason that no statistical significance was found during the data analysis, and, moreover, the differences in bobwhite presence along these routes may not have been great enough to accurately classify some routes as low abundance and some routes as high abundance. In the end, the bobwhite numbers seen along these routes may simply have been too similar, and perhaps all of these routes should have been classified as low routes.

Because bobwhites were actually detected at a small proportion of the stops, this could indicate that all the habitat along these routes was uniformly bad, and it could also indicate that the habitat categories I used may not have reflected quality bobwhite habitat. Rather than habitat quantity, fine scale differences in habitat quality such as floristic composition and landscape connectivity may be better indicators of quail abundance. These factors, however, were not addressed by this study,

All habitat considerations aside, one final possibility is that bobwhites, with their poor dispersal abilities, never fully re-established their populations after the blizzard of 1978. Although bobwhite populations have shown slight increases in the years since the blizzard, this one factor could still at least partially explain the overall decreased presence of bobwhites in southwest Ohio.

MANAGEMENT IMPLICATIONS

Although this study found no significant correlation between land use and bobwhite occurrence, it could be used as a good baseline for further research. Perhaps future studies on bobwhite populations could focus more on assessing habitat quality by looking at specific vegetation types or how different habitat types are distributed and/or connected.

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Appendix A

Summary statistics (means and standard deviations) for the specific habitat types of high and low bobwhite routes at the stop level. Statistics are based on habitat areas covermapped in southwest Ohio in 2004 and outputted from GIS.

	Stop Level Statistics	
Specific Habitat Types	High mean (sd)	Low mean (sd)
Crop	52.31 (27.52)	49.83 (18.68)
Small Grains	0.14 (0.48)	0.54 (1.76)
Pasture/Hay	7.82 (7.00)	8.81 (8.36)
Old Field	7.9 (11.03)	5.68 (6.82)
Warm Season Grass/Forbs	0.77 (3.48)	0.69 (2.06)
Cool Season Grass/Forbs	0.41 (1.42)	0.00 (0.00)
Wetland	0.00 (0.00)	0.13 (0.68)
Open Woodland	0.57 (1.38)	1.19 (3.20)
Closed Woodland	19.03 (13.81)	21.30 (13.26)
Herbaceous Fencerow	0.00 (0.00)	0.02 (0.09)
Shrub/Scrub Fencerow	0.11 (0.42)	0.14 (0.45)
Mature Tree Fencerow	0.00 (0.00)	0.03 (0.12)
Park/Cemetery	0.01 (0.06)	0.02 (0.09)
Residential	10.95 (8.53)	11.5 (11.72)

Summary statistics (means and standard deviations) for the combined habitat types of high and low bobwhite routes at the stop level. Statistics are based on habitat areas covermapped in southwest Ohio in 2004 and outputted from GIS.

	Stop Level Statistics	
Combined Habitat Types	High mean (sd)	Low mean (sd)
Total Crop	52.46 (27.54)	50.37(19.09)
Herbaceous	9.01 (7.04)	9.64 (8.19)
Woody	19.60 (14.06)	22.49 (12.82)
Fencerow	0.11 (0.42)	0.20(0.51)
Developed	10.96 (8.55)	11.52 (11.71)